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ABSTRACT

Arguing that females need instruction in visuo-spatial skills before adolescence, when they begin to lag behind males in the development of these skills that are so strongly correlated with success in technical careers, this paper discusses the use of the three-dimensional and spherical graphics of ExperLOGO to develop spatial skills in students and teachers, and suggests how these activities can complement the curriculum. Topics discussed include recognizing the problem and some solutions to it, both of which are considered in the context of the literature, and the nature of appropriate activities for teaching visuo-spatial skills, including criteria that should be considered in selecting and developing such activities. It is concluded that new computer technologies and software such as ExperLOGO provide unique opportunities not only for the modeling and training of visuo-spatial skills, but also for the investigation of visually mediated learning and the development of visuo-spatial aptitude. A 27-item bibliography of pertinent literature and illustrations of the rotation of a two dimensional object on three axes are included. (MES)

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DEVELOPING SPATIAL SKILLS WITH EXPERLOGO ON THE MACINTOSH

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Research studies consistently demonstrate the existence of two spatial factors: visualization and orientation (McGee, 1979). Visualization, the ability to manipulate two and three dimensional objects mentally, and spatial orientation, the ability to determine the orientation of objects relative to one's body, are strongly correlated with success in various technical occupations as well as with enjoyment and interpretation of drawings or mental images of two and three dimensional objects. There is substantial evidence that visuo-spatial aptitudes can be taught. Males seem to develop these skills either from the curriculum or from other experiences. Females, however, appear to have different curricular or life experiences with spatial tasks, and by adolescence do not perform as well as males on these tasks. Research and intervention have traditionally occurred after females already lag behind the spatial development of males. A more timely and productive intervention strategy may be to provide visuo-spatial training before adolescence, a point at which spatial aptitude differences between males and females begin to appear. This paper (1) discusses the use of the three-dimensional and spherical graphics of ExperLOGO to develop spatial skills in students and teachers and (2) suggests how these activities can complement the curriculum.

Recognizing the Problem

Although an examination of the literature shows conflicting evidence as to the amount, time of onset, and causes of differences in visuo-spatial aptitude, there is a consensus that most females do not achieve the same level of spatial skills as males. Various studies over several decades point to the propensity of females to score lower on spatial tests than males (Barratt, 1955; Fennema and Sherman, 1977; West, 1984). At the same time, sex-related differences in science and mathematics have also been documented (Armstrong, 1980; Pfafflin, 1984) in that boys tend to produce higher achievement scores than girls. Other studies have shown that persons with high spatial abilities have higher achievement and more frequent participation in mathematics (Lowery

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and Knirk, 1982) and in science and engineering (Lantz, Carlberg, and Eaton, 1982). Consequently, the mathematics achievers, scientists, and engineers are more frequently males than females. The implications of such findings are important to consider. There is an underutilization of half the population in careers that are built upon mathematics and the sciences. Not only is a great portion of the population not enjoying the benefits of technology jobs that typically command higher salaries, but the United States is not utilizing a segment of its population that might contribute to scientific innovation and productivity.

What Can Be Done?

There is evidence that visuo-spatial aptitudes can be taught (Bishop, 1982; Lowery and Knirk, 1982; West, 1984; Zavotka, 1985), especially with computer-based activities. Bishop (1980) reported on the successful use of microcomputer video games resulted in spatial visualization acquisition. Research and intervention, however, usually occur after females already lag behind the spatial development of males even though a remedial approach can be more costly and less effective than a proactive approach. A more timely and productive strategy may be to identify critical intervention points so that the visuo-spatial aptitude of females can be maintained at parity with that of males.

The appropriate time for intervention seems to be pre-adolescence. Although spatial skills are shown to be improved with training, the timing of intervention appears to be crucial (Bishop, 1980). A study by Smith and Schroeder (1979) found that fourth graders generally benefited from spatial skills instruction but that there were no significant differences in post-instruction performance between boys and girls. Smith and Litman (1979) replicated the study with 11-13 year-old students in order to determine whether there were differences in spatial visualization ability among early adolescent students and whether instruction would affect boys and girls differently. The investigators found that only the boys benefited from instruction. By combining the results of this study with the results of the earlier Smith and Schroeder study, the authors concluded that girls and boys in the fourth grade benefit from spatial instruction, but instruction postponed to early

adolescence benefits only the boys. Timing of intervention, they concluded, is crucial; pre-puberty may be an optimum time for spatial instruction.

In addition to the timing of the intervention, the type and structure of activities used for intervention are also important elements of an effective approach to developing visuo-spatial skills in females. Hawkins (1984) suggests that the nature of instructional tasks used to teach mathematics concepts is more likely to engage boys than girls. If so, it will be essential to develop tasks which appeal to girls so that they will be naturally inclined to develop spatial skills and pursue mathematical ideas more intensely and extensively. Bishop (1980) posits that focusing upon primary abilities such as spatial aptitude would develop mathematical ability more effectively than just emphasizing mathematics content and skills.

New technologies such as the Apple MacIntosh and its two and three dimensional graphics capabilities provide unique opportunities to investigate the development of visual-spatial aptitude. The MacIntosh is an extremely user-friendly and powerful computer that has scarcely been utilized in education as yet, but promises to be an excellent instructional tool. Both the availability of innovative software and the appeal of the machine and its operating system make the MacIntosh an excellent tool for providing pre-adolescent girls with appropriate spatial development activities.

Interactive computer graphics as available to the learner through the MacIntosh allow the learner to make and test spatial hypotheses. Although Piaget (1971:74) suspected the usefulness of visually mediated learning as compared to the manipulation of objects, the research of Olson and Bualystok (1983: 164-181) presents evidence that direct block manipulation training and visually mediated experiences in block rotations both provided significant results. Furthermore, Salomon (1979) repeatedly documents the effectiveness of modeling spatial representations. The superiority of one mode of learning over another, however, is not the issue as much as the investigation into the effects of learning from types of images that have never before been available. New computer graphics tools allow the modeling of mental skills that don't naturally occur without some sort of mediation.

Several software packages are already available that are appropriate for the development of spatial skills on the Apple MacIntosh or the Apple IIe. Identified programs for the Apple IIe include "Funky Chicken" developed by the

TABS lab at The Ohio State University and currently distributed by Encyclopedia Britannica. Software developed by Sunburst also appears to be useful: "Tip 'n Flip", "The Factory", and "Superfactory". Students using "Tip 'n Flip", for instance, mentally flip a pattern vertically or horizontally until a pattern matches the specified design. The high resolution of the MacIntosh, however, enables the more realistic modeling of the transformations and translations of three-dimensional representations of objects. Enabling Technologies has developed software for the MacIntosh named "Easy 3-D", an advanced hidden surface modeling software for artists, architects, engineers, and designers.

A computer language that promises to be useful for the development of spatial skills is ExperIntelligence's "ExperLOGO", a MacIntosh version of the programming language Logo developed by Seymour Papert and MIT. Like the original Logo, ExperLOGO allows the user to explore mathematical concepts via the computer and to develop visual models of mathematical constructs. ExperLOGO for the Apple MacIntosh, however, provides for exploration in three dimensional space. Activities developed and refined with ExperLOGO would enable young women to use these computer programs to improve spatial skills. Users of ExperLOGO, for instance, are able to render drawings of three dimensional objects on the video display and are then able through Logo commands to rotate that object on the horizontal, vertical, and/or depth axes (see Appendix A). In addition to ExperLOGO, software utilities could be designed and programmed for the MacIntosh that would enhance, extend, or supplement the ExperLOGO activities. Some of these utilities could use computer animation techniques on the MacIntosh.

On the Nature of the Activities

Sensitively designed activities would focus on several primary considerations: appeal, effectiveness, and applicability to the curriculum. For instance, determining the cognitive styles of pre-adolescent females as a way of designing appropriate activities for spatial skills training would be a first step in developing activities that provide conciliatory supplantation, i.e. those activities that remove the cognitive requirements that are causing difficulty and capitalize on the learning preferences of the learner (Ausburn and Ausburn, 1978). However, learner preferences may sometimes inhibit cognitive growth; therefore, it is important to identify those various

combinations and sequences of instructional experiences for spatial skills development. These experiences should not only appeal to learner preferences when appropriate but also stretch learner expectations and abilities. Finally, for successful implementation of the designed activities, the spatial skills training should be linked with regular school curriculum and should include the design of experiences for teachers (usually female) to help them develop their own spatial skills and values for those skills.

Three sets of criteria should be considered for the selection and development of activities:

1) Specific spatial skills must impact strongly on the acquisition of specific mathematics and science concepts in high school and college curricula.

- Spatial skills should enable the interpretation of various forms of scientific, technical and mathematical drawings; for example, orthographic projections (plans, elevations, and end views), cross-sectional drawings, perspective line drawings, and diagrammatic models.
- Spatial skills should enable the imagining of phenomena as they would appear from different angles or at different times.
- Spatial skills should enable simultaneous thinking about multidimensional phenomena.
- Spatial skills should enable not only the mental manipulation of objects or phenomena but also enable the orienting of oneself in three-dimensional space.

2) Spatial skill activities must have strong appeal to girls while taking care to avoid the reinforcement of limiting cultural stereotypes.

- Spatial skills activities should emerge from either the expressed interests of intermediate-grade girls or should be drawn from observable elements in their culture.
- Spatial skills activities should vary depending on socio-cultural milieu.

3) Spatial skill activities must integrate with ordinary intermediate grade curriculum.

- Spatial skills activities should in-so-far-as-possible be designed to substitute for regular activities in the curriculum instead of being added on. In other words, spatial skills activities should show promise for accomplishing regular curricular objectives such as understanding simple machines more efficiently and effectively or developing the ability to read various map representations.

- Spatial skills activities should have a high degree of intrinsic motivation and should be perceived as "important stuff" by students, teachers and parents.

Another important consideration of the implementation of an innovation such as ExperLOGO is the identification of the participating classroom teachers. Although careful identification and planned participation of classroom teachers should always be considered, it is important for this suggested project in two regards. One, although it is important to construct materials that help learners learn, it is also imperative to construct learning materials to help teachers teach. The classroom teacher is an important link between development and implementation and is a source whose perceptions of the utility and effectiveness of instructional materials is not only to be understood but to be sought. Secondly, since most elementary teachers are women, and women tend to have underdeveloped spatial skills, the teacher is likely to be as spatially untrained as the students. This deficiency not only impedes the teacher's own understanding of the usefulness of spatial skills training, but also has inhibited understanding of mathematical and scientific phenomena. Such inhibitions are almost inevitably passed along to students.

Conclusions

New computer technologies and software such as ExperLOGO not only provide unique opportunities for the modeling and training of visuo-spatial skills but also confront researchers and practitioners with a multitude of questions regarding the comprehension of iconic information, static or animated, displayed via computer terminals. New directions are needed in visuo-spatial research if the results of such research are going to be used to develop ability rather than to merely remediate deficient skills. The nature of the tasks used for skill development also need to use the newer technologies

to address the cognitive, social, and affective needs of the target population. The availability of new technologies provides unique opportunities for investigation of visually mediated learning and the development of visuo-spatial aptitude.

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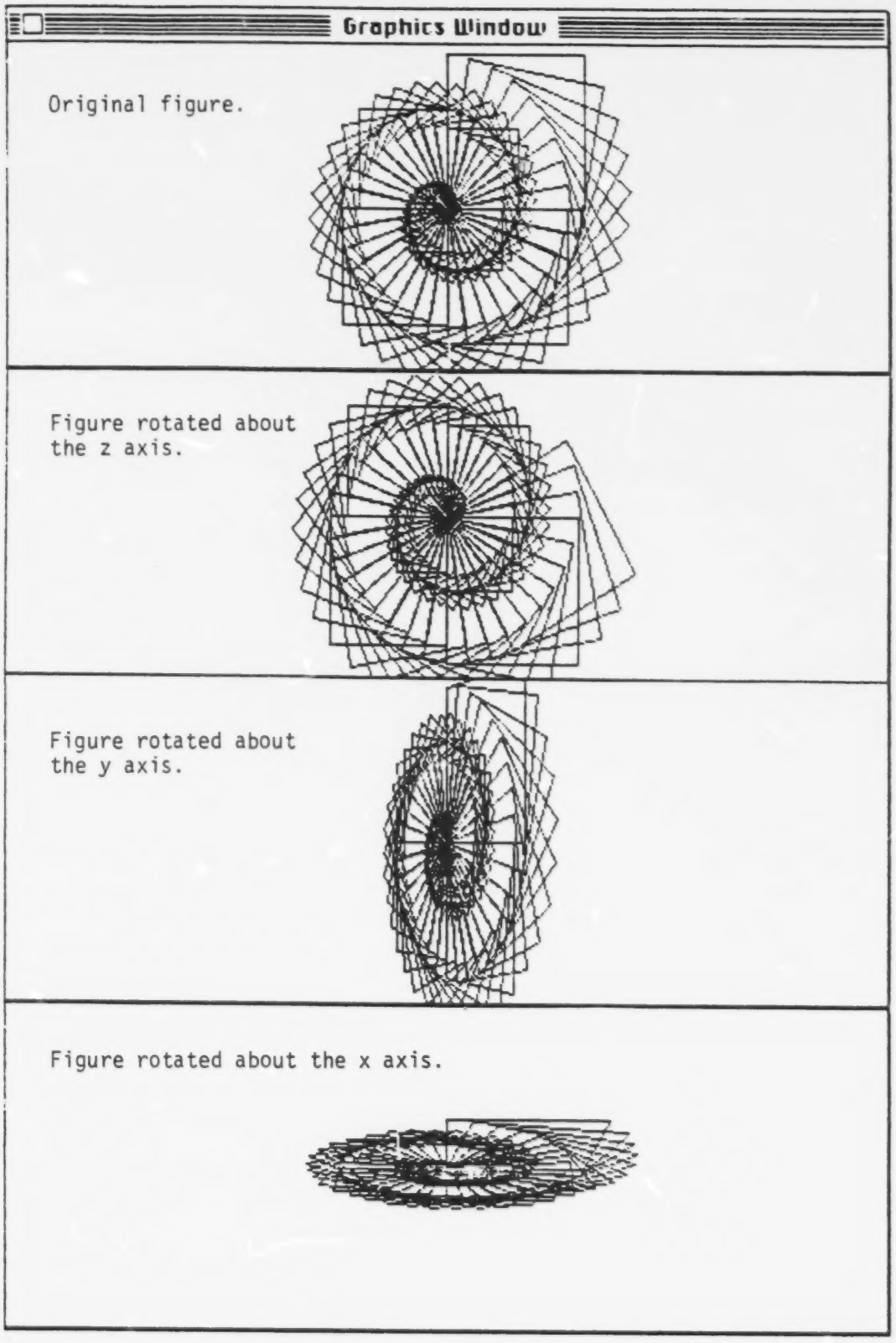
APPENDIX A


Graphics Window
Original figure.
Figure rotated about the z axis.
Figure rotated about the y axis.
Figure rotated about the x axis.

Rotation of a 2 dimensional object on the z (depth), y (longitudinal), and x (horizontal) axes. Software used was ExperLogo^{tm} for the MacIntosh by ExperIntelligence^{tm}.